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LOW BIT RATE DATA COMMUNICATION IN TACTICAL RADIO

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ABSTRACT : *Tactical communication forms the part of Military Communications which only concerns the front end soldiers operating in a theatre environment (formations of division, brigade and below). Mobility is one of the keys to success on the modern battlefield. All communications must be geared to support a combat force that must repeatedly move to survive and fight the enemy. Radio is essential for communications over large bodies of water, territory controlled by enemy forces, and terrain where the construction of wire lines is impossible or impractical. It is also required for air assault operations. As a consequence advance tactical decision support that noe is limited is to advance platforms will become avaiable at much lower level, ranging from different type of vehicles, down to the individual soldier by means of ultra light weight "wearable " equipment. Tactical communication system of today are geared to rather wide area coverage and maderate bandwidth demads providing services like voice communication and low data rate application mainly on point-to-point basis. Low-bit-rate speech coding, at rates below 4 kb/s, is needed for both communication and voice storage applications. The basic properties of the speech signal and of human speech perception can explain the principles of parametric speech coding as applied in early vocoders.*

1. INTRODUCTION

As digital computers and communication systems continue to spread through our modern society, the use of digitized speech signals is increasingly common. The large number of bits required for accurate reproduction of the speech waveform makes many of these systems complex and expensive, so more efficient encoding of speech signals is desirable. For example, limited radio bandwidth is a major constraint in design of the next generation of public mobile telephone systems, and the speech data rate directly influences the bandwidth requirement. In military tactical communications, a system with a lower speech data rate can use less transmitter power to make detection more difficult, or it can allow higher signal to noise ratios to improve performance in a hostile jamming environment. Also, computer storage of speech, such as in voice mail or voice response systems, becomes cheaper if the number of bits required for speech storage can be reduced. These are just some of the applications which can benefit from the development of algorithms to significantly reduce the speech data rate. Mobility is one of the keys to success on the modern battlefield. All communications must be geared to Support a combat force that must repeatedly move to survive and fight the enemy. The single-channel radio is the primary means of communication for command, fire control, and exchange of information, administration, and liaison between and within units. The versatility of radio communications makes it readily adaptable to rapidly changing tactical situations. Radio is essential for communications over large bodies of water, territory controlled by enemy forces, and terrain where the construction of wire lines is impossible or impractical. It is also required for air assault operations. Tactical communication should support the operational units in the field, and must therefore reflect the strategy of the forces. A flexible threat reaction demands very mobile unit which may be spread over a large geographical area. If the forces are to operate under a centralized management and at the same time retain their mobility, heavy demands are put on the communication system. These demands will be in the form of security, survivability, and protection against electronic warfare. The trunk network is today the major tactical communication facility. Its backbone consists of switches mounted in vehicles and interconnected by multichannel radio relays.

2. TECHNIQUE

Amplitude modulation

Single-channel communications radio equipment is used primarily to transmit intelligence in the form of speech, data, RATT, or telegraphic code. Although sound can be converted to audio frequency electrical energy, it is not practical to transmit it in this energy form through the Earth's atmosphere by electromagnetic radiation. For example, efficient transmission of a 20-hertz audio signal would require an antenna almost 8,000 kilometers long. None of the above limitations apply when radio frequency electrical energy is used to carry the intelligence. Great distances can be covered, efficient antennas for

radio frequencies are of practical lengths, and antenna power losses are at reasonable levels.
The frequency of the radio wave affects its propagation characteristics. At low frequencies (.03 to .3 MHz), the ground wave is very useful for communications over great distances. The ground wave signals are quite stable and show little seasonal variation. In the medium frequency band (.3 to 3.0 MHz), the range of the ground wave varies from about 24 kilometers (15 mi) at 3 MHz to about 640 kilometers (400 mi) at the lowest frequencies of this band. Sky wave reception is possible during the day or night at any of the lower frequencies in this band. At night, the sky wave is receivable at distances up to 12,870 kilometers (8,000 mi). In the high frequency band (3 to 30 MHz), the range of the ground wave decreases as frequency increases and the sky waves are greatly influenced by ionospheric considerations. In the very high frequency band (30 to 300 MHz), there is no usable ground wave and only slight refraction of sky waves by the ionosphere at the lower frequencies. The direct wave provides communications if the transmitting and receiving antennas are elevated high enough above the surface of the Earth. In the ultrahigh frequency band (300 to 3,000 MHz), the direct wave must be used for all transmissions. Communications is limited to a short distance beyond the horizon. Lack of static and fading in these bands makes line-of-sight reception very satisfactory. Antennas that are highly directional can be used to concentrate the beam of RF energy, thus, increasing the signal intensity. Amplitude modulation is defined as the variation of the RF power output of a transmitter at an audio rate. In other words, the RF energy increases and decreases in power according to the audio frequencies superimposed on the carrier signal. When audio frequency signals are superimposed on the radio frequency carrier signal, additional RF signals are generated. These additional frequencies are equal to the sum and the difference of the audio frequencies and the radio frequency used. For example, assume a 500 kHz carrier is modulated by a 1 kHz audio tone. Two new frequencies are developed, one at 501 kHz (the sum of 500 kHz and 1 kHz) and the other at 499 kHz (the difference between 500 kHz and 1 kHz). If a complex audio signal is used instead of a single tone, two new frequencies will be set up for each of the audio frequencies involved. The new frequencies resulting from superimposing an AF signal on an RF signal are called sidebands.

Frequency Modulation

Frequency modulation is the process of varying the frequency (rather than the amplitude) of the carrier signal in accordance with the variations of the modulating signals. The amplitude or power of the FM carrier does not vary during modulation. The frequency of the carrier signal when it is not modulated is called the center or rest frequency. When a modulating signal is applied to the carrier, the carrier signal will move up and down in frequency away from the center or rest frequency. The amplitude of the modulating signal determines how far away from the center frequency the carrier will move. This movement of the carrier is called deviation; how far the carrier moves is called the amount of deviation. During reception of the FM signal, the amount of deviation determines the loudness or volume of the signal. The FM signal leaving the transmitting antenna is constant in amplitude, but varying in frequency according to the audio signal. As the signal travels to the receiving antenna, it picks up natural and manmade electrical noises that cause amplitude variations in the signal. All of these undesirable amplitude variations are amplified as the signal passes through successive stages of the receiver until the signal reaches a part of the receiver called the limiter. The limiter is unique to FM receivers as is the discriminator.

DSSS

In direct sequence spread spectrum, we multiply the information-bearing sequence by a much higher-rate pseudorandom sequence, usually generated by some kind of stream cipher. This spreads the spectrum by increasing the bandwidth. The technique was first described by a Swiss engineer, Gustav Guanella, in a 1938 patent application, and developed extensively in the United States in the 1950s. Its first deployment in anger was in Berlin in 1959. Like hopping, DSSS can give substantial jamming margin (the two systems have the same theoretical performance). But it can also make the signal significantly harder to intercept. The trick is to arrange things so that at the intercept location, the signal strength is so low that it is lost in the noise floor unless you know the spreading sequence with which to recover it. Of course, it's harder to do both at the same time, since an antijam signal should be high power and an LPI/LPPF signal low power; the usual modus operandi is to work in LPI mode until detected by the enemy (for example, when coming within radar range), then boost transmitter power into antijam mode.

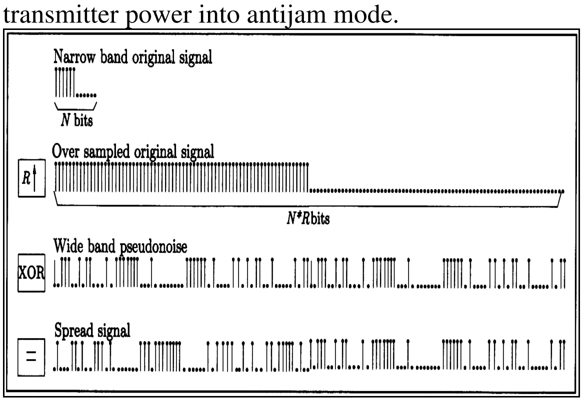

Fig1 spreading in DSSS

3. TRAN CONCEPT

With decreasing military spending it has become of paramount interest to exploit the knowledge and architecture emerging in the fast developing civilian wireless communication industry and whenever possible to reuse civilian equipment and infrastructures for military purposes. In this spirit, we propose the Tactical Radio Access Network (TRAN) concept which is based on the strategy of using civilian technology and architecture to as large extent as possible. All features specific to tactical wireless communications are encapsulated in a few, well defined modules. In current design strategies of the future civilian wireless communication systems (such as UMTS, ITU-2000), the definition of a Generic Radio Access Network (GRAN) concept has been proposed within ETSI and is the baseline architecture of the ACTS project on future wideband radio access system, FRAMES. This concept is described in figure 1 and includes a

• Core Network (CN) and several
• Access Networks (AN)

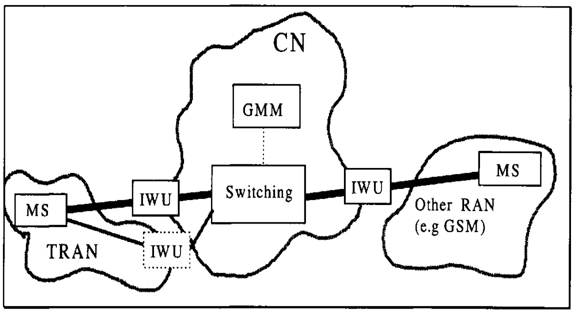

Figure 1: A Tactical Radio Access Network as a component in the civilian GRAN/Core Network concept.

Fig.2 Tactical Radio Access Network

The access network comprises all functions that enable a user access his services and telecommunication partners. It additionally hides all access specific functionality from the core network. In case the access network is a radio network we have a GRAN, and all radio interface related functions should be kept within this access network.

Therefore, the GRAN can have full control over all radio resources. The core network provides both switching and different network services, such as Global Mobility Management (GMM). All GRANs could be realized with existing (e.g. GSM, DECT) as well as with future radio technologies. The services of the core network are available to the various Mobile Stations (MS) of the RANs through gateways, or Interworking Units (IWU). Military requirements on survivability and security, in particular in tactical situations, differ considerably from civilian. However, to a very large extent these special requirements affect only the access network, whereas the core network has the same functionality as for the civilian applications.

The core network technology could thus be reused for military applications whereas special purpose access networks, encompassing the needs of military communication applications, have to be designed. In this proposal where our focus is a tactical scenario, our aim is to use the GRAN-concept to design a Tactical Radio Access Network (TRAN). TRAN is to be designed as an entity with functionality close to an OSI sub-nets (level 3). Functions of the TRAN include all those that are associated with a sub-net, i.e.

• Distributed sub-network control
• Local topology / Mobility management
• Support for global mobility management (handover etc.)
• Radio resource management
• Radio link control
• Physical air-interface

These functions are designed to make the TRAN indistinguishable from any other radio access network as seen from the outside, i.e. to hide all radio related issues from the Core Network. Internally, the TRAN has to fulfill the tactical requirements on performance, security, mobility, reliability and resistance to jamming. One function, that we believe is required in excess of normal sub-net functionality, is gateway redundancy, i.e. the TRAN has to be able to operate reliably even if the gateway (IWU) is physically damaged.

4. BURST COMMUNICATION

Burst communications, as their name suggests, involve compressing the data and transmitting it in short bursts at times unpredictable by the enemy. They are also known as time-hop. Usually, they are not so jam-resistant (except insofar as the higher data rate spreads the spectrum), but they can be difficult to intercept; if the duty cycle is low, a sweep receiver can easily miss them. They are often used in radios for Special Forces and intelligence agents.

An interesting variant is *meteor burst* transmission. This relies on the billions of micrometeorites that strike the Earth’s atmosphere each day, each leaving a long ionization trail that persists for about a third of a second, and providing a temporary transmission path between a “mother station” and an area that might be a hundred miles long and a few miles wide. The mother station transmits continuously, and whenever one of the “daughters” hears mother, it starts to send packets of data at high speed, to which mother replies. With the low power levels used in covert operations, it is possible to achieve an average data rate of about 50 bps, with an average latency of about 5 minutes and a range of 500–1,500 miles. With higher power levels, and in higher latitudes, average data rates can rise into the tens of kilobits per second.

As well as Special Forces, the U.S. Air Force in Alaska uses meteor scatter as backup communications for early warning radars. It’s also used in civilian applications such as monitoring rainfall in Lesotho, Africa. In niche markets, where low bit rates and high latency can be tolerated, but where equipment size and cost are important, meteor scatter can be hard to beat.

5. TACTICAL COMMUNICATION

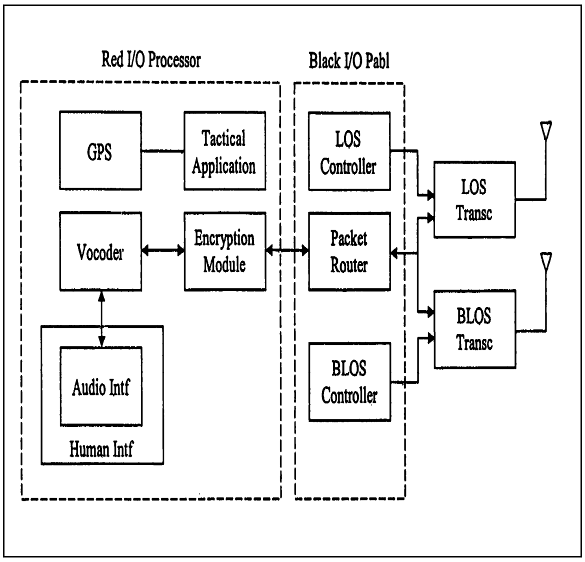

Fig.3 Block dia. Of tactical communication

FIG.3 depicts an exemplary configuration for a radio having a seamlessly integrated satellite communication capability. The radio is comprised generally of a human interface, an encryption module, a packet router, and at least two transceivers. One of the transceivers is configured to transmit data over a wireless communication link at a frequency in the radio frequency spectrum, such as the tactical VHF/UHF spectrum, (referred to herein as LOS transceiver); whereas, the other transceiver is configured to transmit data over a wireless communication link at a frequency in the microwave frequency spectrum, such as the Satcom spectrum, (referred to herein as BLOS transceiver). Each of these radio components, along with other preferred components, is further described below. It is to be understood that only the relevant components are discussed below, but that other known components (e.g., power source) are needed to control and manage the overall operation of the radio. Within the broader aspects of the disclosure, it is also envisioned that these components may be arranged in other varying configurations

The human interface enables the radio operator to control the operations of the radio. For instance, the human interface includes an audio interface for capturing voice data from the radio operator and outputting voice data to the radio operator. Such audio interfaces are well known in the art. The human interface also provides an interface to configure operating parameters of the transceivers. For example, the operator may select at which frequency a transceiver will operate at. In another example, the interface may enable the operator to select which transceiver is used to transmit data. The design also permits the ability to use the radio as a telephone, dialing, and the phone number of any globally existing phone number. The phone number is entered via the front panel, and this phone number is transferred across the BLOS link to the network, which provides a telephony gateway into either a secured VoIP network using the radios embedded encryption, or a secured phone call into the public switched telephone network (PSTN). This allows direct telephony connections between a plain old telephone system (POTS) phone and a radio user. Voice data from the audio interface is routed through an encryption module to ensure secure communication. The encryption device is operable to encrypt and decrypt messages. Although various algorithms are contemplated, the encryption module preferably employs a Sierra Type 1 or a Citadel encryption algorithm. Prior to being encrypted, voice data may pass through a vocoder which digitizes the voice data and then segments it into data packets for subsequent transmission. The data packets are defined in accordance with the Internet protocol or some other type of network routing protocol. In this way, data packets may be routed amongst the transceivers as well as to different nodes in the network. However, it is contemplated that data need not be sent in packet form. A packet router is interposed between the encryption module and the transceivers. The packet router functions in a manner similar to a conventional multi-interface IP router to route outbound data packets to either one or both of the transceivers. It is understood that the radio may be part of an ad-hoc LOS network and; therefore, the packet router will dynamically maintain available nodes in a routing table in accordance with known techniques. Likewise, incoming data packets may be redirected by the router to one of the transceivers. For example, data packets received via a LOS transceiver may be re-routed to the BLOS transceiver for transmission. Connectivity between a LOS radio outstation and the remote LAN will be allowed using security associations' setup to insure authorized access. The LOS transceiver is configured to receive data packets from the router and transmit the data packets over a wireless communication link at a frequency in the radio frequency spectrum. It is readily understood that other types of transceivers which operate within the radio frequency spectrum fall within the scope of this disclosure. Similarly, the BLOS transceiver is configured to receive data packets from the router, but transmits the data packets over a wireless communication link at a frequency in the microwave frequency spectrum. In an exemplary embodiment, the BLOS transceiver is a Broadband Global Area Network (BGAN) transceiver module which operates in the L-band and is commercially available from Immarsat. While a commercially available satellite communication service is presently contemplated, it is understood that the communication link may be established using a proprietary communication service. The radio is equipped with an antenna which is coupled to the LOS transceiver. It is envisioned that the antenna may be detachable or permanently coupled to the radio. A directional antenna is also needed for use with the BLOS transceiver *r*. Therefore, the radio is further equipped with an interface port for detachably coupling a directional antenna to the radio. In one exemplary scenario, the radio operator carries a directional antenna or an omni-directional along with the portable radio. During radio operation, the operator may encounter the need for BLOS transmissions. The operator will then couple the manually steered directional antenna or the omni-directional antenna to the interface port and point the antenna towards a desired satellite. The operator is informed of the precise compass bearing and elevation to aim the directional antenna based on positional information received by the GPS module.

In another exemplary scenario, the portable radio may be situated in a vehicle, on the move, having steerable directional antenna or an Omni-directional antenna. In this case, the radio is coupled via the interface port to the antenna. During operation, the radio will seamlessly route data to either the LOS transceiver or the BLOS transceiver. The BLOS transceiver will in turn route data, along with steering commands, through the interface port to the direction antenna. It is noteworthy that the radio interface as well as the BLOS transceiver is contained within a single portable enclosure. The radio further includes a global positioning system (GPS) module and one or more tactical applications. The GPS module is adapted to receive a timestamp as well as positional information in a manner well known in the art. The tactical application generates tactical awareness data pertaining to the radio. For instance, the tactical application may interface with the GPS module to determine current positional information for the radio. This positional information is in turn embedded in data packets for transmission to a tactical command center. In another instance, the radio may be configured to detect when the radio operator encounters a perilous situation such as nearby explosions or gunfire. In this instance, the tactical application may formulate a message regarding the perilous situation for transmission to a tactical command center. Other types of tactical awareness data are also contemplated by this disclosure. In any instance, tactical awareness data is routed to the encryption module and then onto the router for transmission from the radio.

6. CONCLUSION AND FUTURE SCOPE

In the paper discussed requirements for future wireless tactical networks providing reliable, wideband communication to low level combat units for sensor data, collection and for supporting efficient local tactical decisions. Investigating the fundamental problems of this communication situation leads us to believe that, despite well documented difficulties, distributed control, short range; multihop store-and-forward architectures have definite advantages both with respect to reliability, capacity and power consumption. Additional systems, such as semi-mobile cellular communications systems, will continue to find applications as adjuncts to trunk communications systems. A number of changes are required however. In particular, trunk communications must be extended to below brigade headquarters and the trunk network must be seamlessly integrated with other battlefield networks.

NECESSITY

Low-bit-rate speech coding, at rates below 4 kb/s, is needed for both communication and voice storage applications. At such low rates, full encoding of the speech waveform is not possible; therefore, low-rate coders rely instead on parametric models to represent only the most perceptually-relevant aspects of speech. While there are a number of different approaches for this modeling, all can be related to the basic linear model of speech production, where an excitation signal drives a vocal tract filter. The basic properties of the speech signal and of human speech perception can explain the principles of parametric speech coding as applied in early vocoders. Current speech modeling approaches, such as mixed excitation linear prediction, sinusoidal coding, and waveform interpolation, use more sophisticated versions of these same concepts. Modern techniques for encoding the model parameters, in particular using the theory of vector quantization, allow the encoding of the model information with very few bits per speech frame. Successful standardization of low-rate coders has enabled their widespread use for both military and satellite communications, at rates from 4 kb/s all the way down to 600 b/s. However, the goal of toll quality low-rate coding continues to provide a research challenge.

7. APPLICATION

The various applications are as follows:-

1.It is applied to the Army, Navy, Air Force, and Marine Corps.

2.It is used by multiservice and service components of a joint force.

3**.** Procedures herein may be modified to

Fit specific theater command and control (C2) procedures, and allied and foreign national electromagnetic spectrum management requirements.

4. It is used in military for the purpose of secrecy and surprise balanced against the urgency of communications.

8. ADAVANTAGES

1.Low-rate speech coding can now provide reliable communications-quality speech at bit rates well below 4 kb/s.

2. The goal of toll-quality low-rate coding continues to provide a research challenge.

9. DISADVANTAGES

1. The main limitations associated with the system is considered to be the range with respect to low bit rate services.

2. This is due to the fact that in a TDMA based operation, the slot duration is, at a minimum, only $1/64^{th}$ of the frame timing, which results in either

very high peak power or a low avg. output power level.

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