THIS paper introduces and describes the feature(s) of Solar Network Interfaces used in the infrastructure of a simultaneous synchronous broadcast multi-site wide area cover PMR system (Simulcast) where the interconnecting medium is IP. The primary feature is that of output synchronization. The paper also compare the results of synchronizing over IP and analogue media.

CONTENTS

1 DEFINITIONS

Bulk Delay	See 'Data Delay'.
Data Delay	The propagation delay introduced by the IP network to which the Solar Network Interfaces are connected.
Central Network Interface	A Solar Network Interface configured to interface the IP Network and a Console (Traffic Control Operator).
IP Network	The transmission medium between the Central Network Interface and the Station Network Interface – generally a private high capacity intranet..
Packet Delay	See 'Data Delay'.
Packet Mixing	Data Packets arriving at their destination out of sequence to their transmitted order.
PMR	Private Mobile Radio.
Simulcast	Simultaneous synchronous broadcast multi-site wide area cover PMR system – where the GO (talk-out) Base Tx's all use the same RF. See also 'Simulcast Multi-frequency'.
Simulcast Multi-frequency.	Simultaneous broadcast multi-site wide area cover PMR system – where the GO (talk-out) Base Tx's all use different radio frequencies. Hence there is not a requirement for synchronization. See also 'Simulcast'.
Station Network Interface	A Solar Network Interface configured to interface the IP Network and a Base Station.
Solar/IP Network	The system comprising the Solar Network Interfaces and the IP Network. A standard Solar/IP Network there will be fully duplex.
Network Interface	A Solar Network Interface configured to act either as a 'Station Network Interface' or a 'Central Network Interface'.

2 INTRODUCTION

Simulcast broadcast systems require that the common audio transmitted from a given transmitter is generally ‘in phase’ with that audio being transmitted from other transmitters on the same service.

Simulcast systems using an IP Network as their linking infrastructure have been in use since the mid/late 1990’s; however, their use in PMR is comparatively recent. The problems associated with Simulcast in the super-ordinate system (primarily Base Stations and coverage) have not changed but the nature of the problems of synchronization over the infrastructure have.

3 COMPARISON OF SYNCHRONIZATION ERRORS IN SYSTEMS

In Simulcast systems using an analogue infrastructure the commissioning or maintenance technician required a knowledge of the four concepts of ‘Group Delay’, ‘Intercept Error’, ‘Bulk Delay’ and ‘Line Reversal’ in order to identify problems and apply corrective adjustment (see last paragraph ~ “Bibliography …..”). With a Simulcast over IP Network system there is little that a technician can do to rectify error; however it is essential for speedy fault diagnosis that the sources of error, and how the system handles these errors, are understood.

3.1 Errors in Analogue infrastructure

a. Bulk Delay
There is a requirement for Bulk Delay compensation in an Analogue infrastructure. Synonymous with ‘Packet Delay’ in an IP Network.

b. Group Delay
There is a requirement for Group Delay compensation in an Analogue infrastructure.
There is no requirement for Group Delay compensation within a Solar/IP Network.
However, there may be such a requirement in the super-ordinate system.

c. Intercept Error
There is a requirement for Intercept Error compensation in an Analogue infrastructure.
There is no requirement for Intercept Error compensation within a Solar/IP Network.
However, there may be such a requirement in the super-ordinate system.

3.2 Errors in IP Network infrastructure

a. Packet Delay
Synonymous with ‘Bulk Delay’ in an Analogue infrastructure. There is a requirement to compensate for variable and varying delay in order to synchronize the data.

b. Packet Mixing
There is a requirement to compensate for an error found in IP Networks where packets arrive out of sequence to their transmitted order.

c. Packet Missing
There is a requirement to compensate for an error found in IP Networks where a packet does not arrive at its destination or arrives so late that it is considered as ‘missing’.

3.3 Errors common to systems with Analogue and IP Network infrastructure

a. Line Reversal
An error found in analogue infrastructures and in Base Station and site wiring.
There is no requirement for Line Reversal compensation within the Solar/IP Network.
There is a possibility of such an error in the super-ordinate system which can be remotely and manually corrected by the Station Network Interface.

4 SYNCHRONIZATION AND ERROR DETECTION - BASICS

4.1 Introduction

Solar Network Interfaces adopt methods commonly used for some years by the commercial broadcast sector in Europe with its Digital Audio Broadcasting (DAB) service; these methods are used in the timing and error recovery processes to ensure that signals are both synchronous and meaningful.

The “EUREKA-DAB” project (147) was started in Europe in the early 1990s giving rise to ITU recommendations. For sources of information see paragraph 5, ‘Bibliography’.

The Synchronization and Error recovery processes generally take place in the receiving Network Interface. The normal state of the Solar/IP System is such that there is no input and therefore no output; the output will actually be silence. The purpose of the Solar Interface system is to fill-in this silence with meaningful information, based on the original input to the system, such that the signals on the multitude of outputs are in synchronization.

4.2 Packet Delay

Within the originating Network Interface the Data Packets are tagged with synchronization information before being delivered to the IP Network; synchronizing information is related to a globally available off-air signal. The receiving Network Interface, also with access to the off-air signal, retrieves the synchronizing information and delays the next stage of the process until a pre-determined time is reached. On reaching that time all similar packets in the system are released for onward processing – in synchronization.

4.3 Packet Mixing

An emergent effect of the synchronization process is that the receiving Network Interface has knowledge of the correct packet order or sequence. If packets are out of sequence then they can – to a greater or lesser extent – be re-ordered.

4.4 Packet Missing

Another emergent effect of the synchronization process is that the receiving Network Interface has knowledge of the fact that a packet is missing. If a packet is missing the output stream can be constructed to compensate such that the result is meaningful.

5 SYNCHRONIZATION AND ERROR RECOVERY - METHOD

5.1 Packet Delay

In a well engineered system the IP network characteristics will be well known and dependable. The commissioning engineers will use their knowledge of the network and analysis tools to determine the Maximum Packet Delay (MPD) expected and allowable.

At the originating Network Interface the data packets of speech are compressed using an established algorithm, multiplexed with signalling information and error detection data. An absolute time-stamp – “Time Of Origin’ (TOO), originated from a GPS receiver, and a sequence number are added.

At the destination Network Interface absolute time information is obtained from a GPS receiver. When the data arrives at a destination Network Interface it is held in a buffer until the time TOO + MPD is reached. Then the data are decompressed, converted to an analogue form and passed to the transmitter. In this way all the transmitters in the simulcast system receive modulation signals synchronously regardless of the various network delays.

Packets arriving whose propagation time exceeds MPD are treated as missing and discarded.

The Traffic Manager sends error correction information to all the destination Network Interfaces in every packet and a setting for the MPD at intervals. The time of arrival at Station Network Interfaces is recorded and actual delay calculated. Error detection is also performed. The resulting information is sent to the Traffic Manager over the return channel for quality of service (QOS) analysis.

The QOS information is used to monitor system performance and generate a report as necessary. The need to alter the MPD value in the light of QOS information received from the Station falls to the system maintainer.

5.2 Packet Mixing

The destination Network Interface is able to re-order packets which have arrived in its delay buffer in a mixed order and correct their order by examination of the sequence number. Clearly this can only be possible within a time frame not exceeding the MPD.

5.3 Packet Missing

If an individual packet is missing its position in the output stream may, optionally, be filled with a pseudo packet which is derived from an interpolation of previous packets or silence.

An anti-jitter buffer is available to smooth the reception of a predetermined number of "bunched" packets. The size of this buffer is configurable via the Engineering Terminal.

In the event of continuous packet loss the audio output is muted and the transmitter can be inhibited.

5.4 Loss of GPS

In the event of loss of the GPS signal at a destination Network Interface the transmitter will be automatically inhibited; a transmitter out of synchronism can seriously impair a simulcast network. However this can be manually overruled by the system controller, if required, and the offending station put into Unicast mode.

To overcome this situation a secondary source of timing signal is available. This high stability source which is external to Solar will be conditioned to be phase coherent with the GPS signal before it was lost. It can then continue to maintain the timing signal within the acceptable tolerance for simulcast operation for many days and permit the continued operation of the site until the GPS signal is restored. The same situation and solution can be applied at the Central Network Interface location.

6 BIBLIOGRAPHY AND FURTHER READING

Papers offering useful insight to the understanding and effective use of Simulcast PMR.

"Simulcasting Without (Too Many) Tears" – Update of a paper presented by R. Atack at the 1989 APCO Conference in Sparks, Nevada
(Available on the web: - http://quasi-sync.atackscomputers.co.uk)

"Simulcast Briefing" by D Cahill. Dalman Technical Services Ltd.
File SimulcastBriefing.doc* (Available on the web: - http://www.dalmants.co.uk)

Sources of information on Digital Audio Broadcasting (DAB) and synchronizing techniques.

ETSI The relevant DAB standards are:

ETSI TR 101 496-3 - The last paragraph of Section 4.4.3.2 describes the GPS usage.
ETS 300 799 (Sept 1997) - Annex C describes the time-stamp specification in detail.

To download these papers it is necessary to register with ETSI, but it's free, The search page is: http://pda.etsi.org/pda/queryform.asp put the following in the search box, with the "Standard Type and Doc No" box ticked.

"TR 101 496-3 V1.1.1" and "ETS 300 799" – (Click the download symbol on the right).

Arqiva and ntl Links to Arqiva and ntl papers and engineering information.

http://www.ntl.com/locales/gb/en/guides/anoraks/networks.asp#5.2.1.4

http://www.broadcastpapers.com/radio/index.cfm?objid=47

Eureka 147 and BBC Engineering are probably additional sources worth investigating.