2.0 EXPERIMENTAL SET-UP

2.1 Introduction:

Almost all stations install separate phase and amplitude recording systems for satellite radio beacon (RB) experiments. Such installations usually use separate antennas and receiving units for phase and amplitude records. Normally the amplitude recording system uses a pair of crossed yagi along with its associated hybridquadrature and receiver. Sometimes to achieve a high signal to noise ratio phase switching technique similar to radio interferometry has also been used (Koster, 1970). Scintillation studies using stellar radio source calls for use of much more elaborate arrangements, viz., radio interferometers (Kufenach, 1971).

When a plan was laid for an experimental set-up to be used for receiving the VHF beacon from ETS II in this station, it was decided to design a system capable of providing phase as well as amplitude records by using the same antenna and receiver. The design objective was set at reducing expense in hardware to a minimum at the same time making the equipment simple yet reliable. This has been made possible by introducing a modification to a Titheridge type (Titheridge, 1966) radio phasemeter. This modification was in the form of a so called 'sampling technique' which is explained in this chapter. Another important extension of the equipment was an arrangement for the measurement of ellipticity of the received signal which is believed to be useful in better understanding of transionospheric refraction of radio wave with relation to ionospheric irregularities like plasma.
oucoles. It may be recalled that considerable importance has been assigned to plasma outcules (Basu and Kelley, 1977; Basu and Basu, 1981) for their association with intense equatorial scintillations.

Table 1. Details of ETS VHF radio beacon

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
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<tbody>
<tr>
<td>Orbit</td>
<td>Geostationary</td>
</tr>
<tr>
<td>Position of ETS II</td>
<td>130° E longitude</td>
</tr>
<tr>
<td>VHF RB frequency</td>
<td>136.1123 MHz</td>
</tr>
<tr>
<td>RF output</td>
<td>2 watts</td>
</tr>
<tr>
<td>Polarization</td>
<td>Circular</td>
</tr>
<tr>
<td>Modulation</td>
<td>PCM at 250 bits/sec.</td>
</tr>
</tbody>
</table>

2.2 Working principle of the signal amplitude recording system:

In a Titheridge type radiophasemeter the receiving antenna which is normally a multi element yagi is kept rotating about its axis to sense the polarization phase of the received signal. Now to measure the amplitude of the signal, the output from the detector stage of the receiver is sampled for small duration at four positions spaced 90° apart while the antenna makes one complete revolution. The sampled output is averaged and recorded in analog form on a strip chart recorder. This is to be noted that due to the low looking angle (38°) of ETS II from this station, the RB signal appears to be highly elliptically polarized even though it originates as circularly polarized at the satellite. Due to this nature of the received signal the output from the detector stage of the receiver undergoes quasi sinusoidal variation as the antenna rotates. Again due to Faraday rotation, the orientation of
Fig. 1: Sampling plan for the incident elliptically polarized wave.
the ellipse of polarization goes on changing with time. Here the samplings are done always along the major and minor axes of the ellipse irrespective of its orientation in space. This is illustrated in Fig. 1.

2.3 Instrumentation:

The complete equipment for signal amplitude measurement can be regarded as the integration of the following functions:

(a) Signal reception
(b) Signal processing
(c) Signal sampling
(d) Averaging the sampled signal and recording.

Hardware implementation of the above functions are done as detailed below.

(a) Signal reception - For receiving the signal from the satellite at 136.1123 MHz a six element yagi antenna designed at 136 MHz is used. The gain of the antenna is estimated at about 10 dB. A worm gear - motor arrangement is adopted to keep the antenna rotating at the rate of one rotation in about one second. The weak signal picked up by the antenna is amplified by a pre-amplifier which is then down converted to 8.95 MHz by a crystal controlled MOSFET converter. A BEL communication receiver (model KG2003) is then used to handle this signal. In the receiver a second conversion takes place to bring the signal frequency to 460 KHz. A three stage IF amplifier (bandwidth narrowed down to 5 KHz) makes the signal strong enough to be processed after detection.

(b) Signal processing - Inspite of the narrow bandwidth of the communication receiver the signal as obtained from the
detector stage is embedded in random noise and is still small. Processing of this small signal is done in a simple but very effective way.

As mentioned earlier, the output from the detector stage of the receiver undergoes quasi sinusoidal variation at a frequency of about 2 Hz due to the rotation of the antenna. An operational amplifier circuit with high negative feedback at higher frequencies is used to amplify this 2 Hz signal. This amplified signal is then further processed in a low-pass active filter. The output from the active filter is almost noise free and is of sinusoidal nature with frequency of 2 Hz. A pulse shaper unit transforms this sine wave into a positive going square pulse train while maintaining the phase relationship with the rotating yagi. The pulse repetition rate being same as the frequency of the sine wave input while pulse duration is about 200 ms.

(c) Sampling of the signal - To sample the receiver output at four equally spaced positions of the antenna while it makes one complete rotation, four sampling pulses are generated in a circuit described here. These pulses drive a FET switch which enables the sampling amplifier to sense the receiver output. To achieve this a few delay generators and triggered pulse generators are used.

Whenever the antenna plane coincides with the major axis of the ellipse of polarization, the output from the detector stage of the receiver attains the signal peak. Similarly, when the yagi plane coincides with the minor axis of the ellipse, the output from the detector stage reaches the minimum signal level. Now, to ensure that sampling pulses are generated only when the antenna plane coincides with the major and minor axes of the ellipse of
polarization, the following arrangement is adopted.

As can be seen from the block diagram (Fig. 2), delay generator-I gives out a sharp pulse when triggered by the rising edge of the positive going output pulse from the pulse shaper unit. The timing diagram (Fig. 3) shows clearly the relationship of antenna positions with different pulses along with their pulse durations. It may be noted that the output pulse from the delay generator-I almost coincides with the peak signal position of the antenna. This pulse triggers timer-I which in turn gives out the first sampling pulse. Delay generator-II which is triggered simultaneously with timer-I, produces a wide positive going pulse. The falling edge of this pulse is used to trigger timer-II which of course produces the second sampling pulse. The duration of these two sampling pulses are normally made equal and kept within 20 to 40 ms. It is evident from Fig. 3 that the antenna has rotated through 90° from its peak signal position during this time, i.e. the 2nd pulse is generated when the antenna reaches a minimum signal position. By the time the antenna rotates through 180° from its initial position, the 2nd peak signal position is reached. In a similar way other two sampling pulses are generated during the other 180° rotation of the antenna. Thus four sampling pulses are generated in one complete rotation of the antenna such that they are consecutively locked to the maximum and minimum signal positions of the antenna. In other words, samplings will take place along the major and minor axes of the ellipse of polarization irrespective of its orientation in space.

A suitable DC level is assigned to this sampling pulse train which is then used to operate the FET switch. Whenever a sampling pulse arrives at the gate terminal of one FET, the
Fig. 2: Block diagram of the experimental set-up.
Fig. 3: Timing diagram.
output from the detector stage of the receiver reaches the sampling amplifier.

(d) Averaging the sampled signal and recording - The output from the sampling amplifier is of pulse nature for which it cannot be recorded as such. This output from the sampling circuit has to be averaged in a simple RC network having a time constant of about 1.5 sec. To obtain better linearity of the voltage appearing across the RC network with changing signal level a small fraction of the relatively high output voltage from the sampling amplifier is used to charge the capacitor. With a sampling pulse duration of 20 ms and employed recording system, it was found that system optimization is achieved at a RC time constant of 1.56 sec. The small voltage appearing across the RC network is suitably amplified in a d.c. amplifier and the amplified signal is then recorded in an Easterline Angus strip chart recorder. A small amount of 50 Hz AC signal is mixed with the averaging RC network output to help the chart recorder stylus to follow rapidly any change in signal amplitude. Chart speed set at 12 inch per hour, the system is able to provide record of scintillation events that could be resolved up to 8 fades per minute. On very rare occasions it was observed that the fade rate exceeded this upper limit of resolution.

The lower part of Fig.2 shows the arrangement for ellipticity measurement experiment (Bardoloi et al., 1982). It may be noted from Fig.2 that the comparator compares the signal levels at maximum and minimum position of the antenna and records their ratio as a measure of ellipticity of the received signal. The sampling and recording methods are same as in amplitude measurement system.
2.4 System consideration:

It is to be expected that due to sampling technique adopted here, the chance of avoiding a short burst type noise will be greater compared to a conventional stationary crossed yagi recording system. This is a desired feature as it will raise the signal to noise ratio of the system. A higher S/N ratio offers a wider dynamic range for observing deeper fades. To evaluate the S/N ratio theoretically, the basic transmission loss (Jordan and Balmain, 1969) is considered first. From the satellite to the receiving antenna, the transmission loss is given by

$$ L_b = -10 \log \left( \frac{4\pi d}{\lambda} \right)^2 \text{ dB} $$

Where $d =$ distance from the satellite to the receiving antenna,

and $\lambda =$ wavelength of transmission

For ETS II, it turns out to be $L_b = -166 \text{ dB}$. Considering the satellite antenna to be isotropic i.e. with gain $G_t = 0 \text{ dB}$ and receiving antenna gain $G_r = 10 \text{ dB}$, the received power level of the signal will be $S = -153 \text{ dBW}$ (for radiated power from ETS II is 3 dBW).

Now to compute the noise power level, the relation

$$ F_n = 1 + \frac{T_e}{T_0} $$

is considered.

Where, $F_n =$ noise figure of the receiving set-up

$T_e =$ equivalent noise temperature of the receiving set-up

$T_0 = 290^\circ \text{K}.$

For the receiving set-up used in this experiment noise figure is 4.5 dB which corresponds to a noise temperature $T_e=580^\circ \text{K}.$ Again the mean antenna temperature that could be expected
at 136 MHz (Dolukhanov, 1971) is $-380^\circ K$. Thus noise power level for the receiving system is given by

$$N = k (T_e + T_a) B \text{ watts.}$$

Where, $k = 1.38 \times 10^{-23} \text{ W oK}^{-1} \text{ Hz}^{-1}$

$T_a = \text{antenna temperature, } ^\circ K$

$B = \text{bandwidth, Hz}$

For $(T_e + T_a) = 960^\circ K$ and $B = 5 \text{ KHz}$ at 3 dB, the noise power amounts to

$$N = -164 \text{ dBW.}$$

Which puts the $S/N$ ratio at 11 dB. Against this theoretical value a typical measured signal to noise ratio was found to be 9 dB. This may be considered as a good agreement between computed and measured values. It is obvious that the $S/N$ ratio may be increased by making samplings only along the major axis of the ellipse of polarization, i.e. when signal level is maximum. This will mean only two samplings per second which will necessiate the use of higher time constant in the RC network for averaging. In consequence to this large time constant the recording system will be sluggish to fast scintillation events.

2.5 Calibration:

Calibration of the dynamic range of the equipment is manually checked everyday. Calibration source used was a Marconi signal generator (Model TF 801/1). But it was found difficult to make the calibration directly at the signal frequency as the generator frequency goes on changing inspite of allowing sufficiently long warming up time. So as a precautionary measure the receiver was additionally calibrated at 1st conversion frequency, i.e. 8.95 MHz by using another Marconi signal generator (Model TF144H).