THE CO-EXISTENCE OF SPREAD SPECTRUM RANGING SIGNAL IN INDIAN NATIONAL SATELLITE-1B (INSAT-IB) WITH TV OR SCPC CHANNELS

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ABSTRACT

Spread Spectrum Systems have the potential of sharing the frequency spectrum with broadcasting, telephony and data communications services due to their low power density signalling. The study of feasibility of co-existence of Direct Sequence Spread Spectrum ranging signal with TV or SCPC carriers in a common satellite transponder is presented in this paper. The suitability of this type of ranging for Indian National Satellite-IB (INSAT-IB) system from Master Control Facility (MCF), Hassan, India has been examined. The mutual interference effects between spread spectrum ranging signal and TV or SCPC services through various sizes of earth stations in INSAT network have been calculated. The study indicates that simultaneous accurate range measurement by spread spectrum technique from control earth station is possible without any significant degradation in signal quality of TV or SCPC services.

INTRODUCTION

There has been a considerable increase in interest in the use of Spread Spectrum (SS) techniques to meet some specific requirements in communications and navigations. SS systems have the potential of sharing spectrum with the broadcast or communication channels because of their low power density signalling characteristics. Co-channel interference of high levels is rejected in SS receiver by the auto correlation process employed. Studies have been carried out by some research organisations and educational institutions to find out the feasibility of co-existence of SS with other users on a mutually non-interference basis. (1)-(5) FCC, USA has examined the condition under which SS land mobile communication channel and TV can share the spectrum. NASA/GSFC, USA has conducted Spread Spectrum Multiple Access (SSMA) experiment thorugh a satellite and experimental results show that simultaneous transmission of acceptable SS and TV are feasible. University of Bath, UK has studied the conditions which would allow land mobile radio systems using SS technique to share certain RF allocations on a mutually noninterference basis with the existing TV channel. Carleton University, Canada has conducted the study for the use of SS modulation to facilitate the insertion of data signal into the standard TV signal. Space Applications Centre (SAC), ISRO, India has developed a 4 MHz spread spectrum voice communication system and experimented for its co-existence with FM signal via APPLE (Ariane Passenger Payload Experiment), the first Indian experimental communication satellite.(6), (7) This system is later modified for ranging function. The ranging experiment with INSAT-1B has been carried out from ISRO's earth station at Delhi and the results obtained are satisfactory.

The objective of the study presented in this paper is to theoretically examine the feasibility of co-existence of wideband Direct Sequence (DS) type SS ranging signal with FMTV or narrow band SCPC signal in overlapping mode through a C-band transponder of Indian National Satellite-1B (INSAT-1B). INSAT-1B is a multipurpose geostationary satellite system for domestic telecommunications and meteorology with capability for nationwide direct TV broadcasting to rural communities in India. (8) The major characteristics of C-band transponder, earth stations planned in INSAT- network for various services and systems under study have been described in this paper in brief. The mutual interference effects in the performance of systems for the above cases in study have been calculated. The study indicates that simultaneous SS ranging along with TV or SCPC service is possible through a satellite transponder without any significant degradation in TV or SCPC system performance.

RANGING SYSTEM DESCRIPTION

Fig. 1 shows the simplified block diagram of spread spectrum ranging system. In this system, data at 10 kb/sec is modulo-2 added to a Pseudo Noise (PN) code at 20.47 Mb/sec and is then used for Bi-Phase Shift Keying (BPSK) 70 MHz IF carrier which is filtered over 36 MHz bandwidth before transmission. At the receiver, 70 MHz IF signal is filtered over a bandwidth of 36 MHz and is given to the heterodyne correlator. After perfect code synchronization, data at 10 kb/sec modulated over 10 MHz carrier is obtained from the correlator which is fed to the BPSK demodulator for recovery of data. Table-I gives the specifications of SS ranging system.

The high bit rate PN code of length 2047 bits employed for spreading is generated by using 11 stage feedback shift register and a 20.47 MHz clock. The low bit rate PN code of length 8191 bits employed for range ambiguity resolution is generated by using a 13-stage feedback shift register and a 10 KHz clock. The initial pattern pulse of spread PN code and that of range ambiguity PN code of the transmit section are gated to generate the start pulse for the time interval counter and the same initial pattern of the received spread PN code and that of ambiguity PN code are gated to generate the stop pulse for the time interval counter. From the time delay thus measured, the range value can be calculated. The accuracy of range is determined primarily by spread PN code rate, code jitter and resolution time of time interval counter.

SYSTEM CONSIDERATION

For ranging, C-band transponders have been considered. INSAT-IB has 12 transponders operating in C-band out of which one is used for TV distribution and the rest for various telecommunication services. Each transponder has a bandwidth of 36 MHz, EIRP of 32 dBw and G/T of -4.5 dB/°K over the primary coverage.(9)

Master Control Facility (MCF), Hassan is a control earth station which provides telecommand, telemetry and ranging operations on INSAT-IB. The services offered by the earth stations and the main characteristics of all the earth stations in INSAT-IB network are given in Table-II.

Three types of services considered for the purpose of study are TV, SCPC, and SS. The major characteristics of these systems are indicated below briefly.

<u>TV System</u>: TV broadcast service is also being provided using C-band transponder besides normal S-band transponders. For single TV transmission, 20 MHz FM bandwidth is used. Two FMTV carriers with 16 MHz bandwidth each have also been considered in INSAT-IB network for providing increased number of TV channels. The minimum C/N required in service at type A earth station is 14 dB and that for a type New-1 earth station is 11 dB for TV reception of desired quality.

<u>SCPC System</u>: SCPC service is provided to cater to the needs of subscriber using various earth stations (Table-II). Each SCPC carrier has a channel spacing of 45 KHz and different channels are allotted to various users. For SCPC transmission, FM or DM/QPSK modulation is used for base band voice signal. The minimum C/N required in SCPC service at any type of earth station is 12 dB to provide satisfactory audio signal quality.

<u>SS ranging System</u>: SS system is considered for ranging from MCF. For ranging signal, BPSK modulation is used and has a spread bandwidth of 36 MHz. Higher PN code used provides range resolution and lower PN code used provides unambiguous range. The minimum C/N required for ranging signal in MCF is kept at -20 dB to provide a bit error probability of $1x10^{-6}$ or better so that the range resolution obtained is within specified value.

MUTUAL INTERFERENCE

Considering the types of services in INSAT network, three combinations of services have been examined for coexistence in a single C-band transponder.

Case-I Spread spectrum ranging and single FM TV carrier
Case-II Spread spectrum ranging and two FM TV carrier
Case-III Spread spectrum ranging and single channel per carrier (SCPC)

The entire available satellite power is assumed to be consumed by the simultaneous users in the mutual interference calculations as worst case consideration.

The processing gain G_p of DS SS receiver is given by

$$G_p = \frac{(S/N)_{out}}{(S/N)_{in}} = 2B_{S_{in}} T_S S \quad ----- \quad [1]$$

Where $(S/N)_{out}$ = output signal to noise power ratio
$(S/N)_{in}$ = input signal to noise power ratio
$2B_{S_{in}}$ = RF bandwidth of input signal
T_s = information bit time duration.

This expression for processing gain is modified when interfering signal is present. For the case in which the bandwidth of the input interfering signal is less than or equal to the bandwidth of the input desired signal, the processing gain G_p is given by (10)

$$\frac{(S/I)_{out}}{(S/I)_{in}} = 2B_{S_{in}} T_s \left[\frac{\frac{1}{S_{in}(\Delta W/2B_{S_{in}})}}{(\Delta W/2B_{S_{in}})} \right]^2 \quad ----- \quad [2]$$

Where $(S/I)_{out}$ = output signal to interference power ratio
$(S/I)_{in}$ = input signal to interference power ratio and
ΔW = the radian frequency difference between the desired signal and interfering signal.

When the bandwidth of interference is greater than the desired signal, G_p is given by

$$\frac{(S/I)\ out}{(S/I)\ in} = \frac{2B_{S_{in}} T_s \left[B_{I_{in}} / B_{S_{in}} \right]}{\left[\dfrac{S_{in}(\Delta W/\ 2B_{I_{in}})}{(\Delta W/\ 2B_{I_{in}})} \right]^2} \qquad \text{-----} \qquad [3]$$

Where $B_{I_{in}}$ = bandwidth of input interfering signal.

This expression indicates that the system gain is proportional to bandwidth filtering ratio.

Eqn. [2] gives FM TV interference on SS signal when there is frequency offset between the two carriers. Eqn. [3] gives SS interference on TV or SCPC with or without offset in frequency between SS and TV or SCPC carrier. Table-III shows the receive C/N degradation in performance of the systems in mutual interference conditions. The values in bracket indicate the C/N values obtained in the absence of interference.

<u>Case I</u>: C/N value for single FM TV carrier reduces from 22.7 dB to 19.7 dB at type A station and from 14.7 dB to 14.06 dB at type New 1 station when there is no frequency separation between ranging carrier and TV carrier. With frequency offset of 12 MHz, C/N of TV carrier is degraded by 1 dB and by 0.18 dB at Type A station and New 1 station respectively. The final C/N value obtained is still above the desired objective of 14 dB and hence there is no degradation in system performance.

C/N of ranging carrier is reduced to -20.02 dB and -14.67 dB at MCF with no frequency offset and with 12 MHz frequency offset respectively between ranging carrier and TV carrier. The final C/N of about -20 dB obtained is within the correlator performance limit and so ranging accuracy is not affected significantly.

<u>Case II</u>: C/N of FM TV is reduced from 19 dB to 17.8 dB and from 11 dB to 10.79 dB at type A station and type New 1 station respectively with SS carrier at the centre of the band and TV carriers spaced at 10 MHz on either side of SS carrier. The reduction of C/N at New 1 station by 0.21 dB from desired value of 11 dB should not cause any significant degradation in system performance.

C/N of ranging carrier is reduced to -16.17 dB at MCF, Hassan under the above situation and the final C/N obtained is well above the minimum C/N requirement of -20 dB in SS receiver for the desired performance.

<u>Case III</u>: C/N has been reduced from 14 dB to 12.3 dB at the major type A earth station and from 14 dB to 13.97 dB at the smallest type New 1 earth station in the network. Since

the final receive C/N values are found to be above the desired value of 12 dB, the SCPC system peprformance is not degraded.

At MCF, C/N of ranging carrier is reduced to -20.05 dB. This reduced C/N value is less by only 0.05 dB as compared to the desired value of -20 dB and this does not cause any significant degradation in ranging system performance.

Thus the above calculations show that SS ranging signal and TV or SCPC can coexist in a single transponder without affecting significantly the performance of any of the systems.

CONCLUSION

The study indicates that accurate range measurement by spread spectrum technique with ranging signal sharing TV or SCPC channels in an overlapping mode in a single transponder is possible. Acceptable quality of TV or SCPC signal is obtained under simultaneous transmission condition. The accuracy of range obtained better than that can be achieved by other conventional methods and hence it seems to be a very useful method for ranging of communication satellites.

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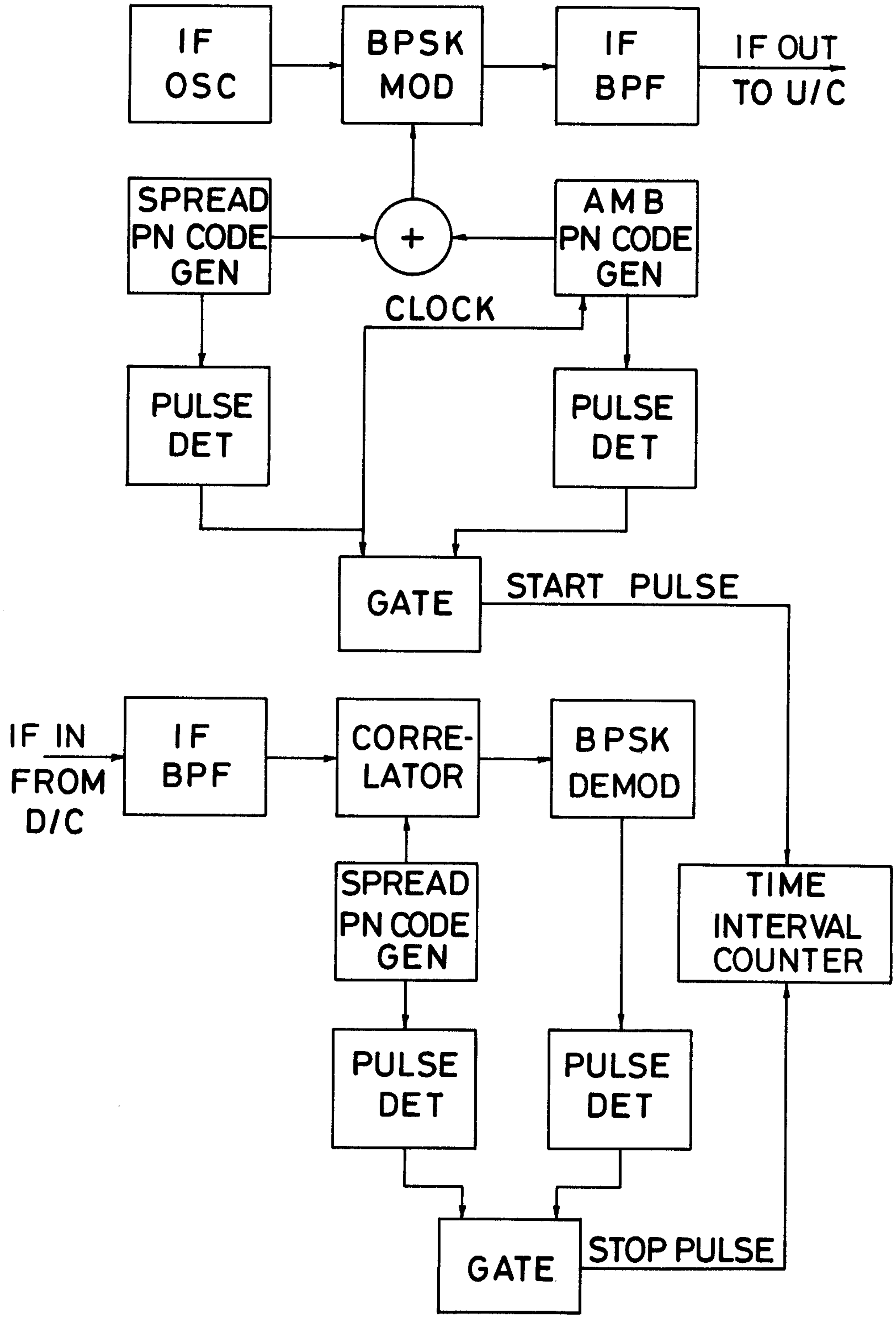

FIG. 1 SPREAD SPECTRUM RANGING SYSTEM

Table-I
SPECIFICATIONS OF SS RANGING SYSTEM

Spread PN code clock	20.47 MHz
Spread PN code length	2047 bits
Ambiguity PN code clock	10 KHz
Ambiquigy PN code length	8191 bits
Transmit/Receive IF	70 MHz
IF Modulation	BPSK
IF Bandwidth	36 MHz
Receive correlation	Heterodyne
Min Input C/N	-22 dB
BER	1×10^{-4}
Max. code jitter	±10%
Resolution of Time interval counter	±10 nsec.

Table-II
SUMMARY OF EARTH STATIONS IN INSAT-IB NETWORK

Type	Antenna diameter	G/T dB/°K	Primary Service
MCF	14.0	34.5	Network control
Type A	11.8	31.7	TV, SCPC, FDM-FM
Type B	7.5	25.7	SCPC, FDM-FM
Type C	4.5	19.7	SCPC
New 1	6.1	23.7	TV
New 2	3.0	16.7	SCPC
New 3	2.0	13.2	SCPC

Table-III

RECEIVE C/N IN MUTUAL INTERFERENCE CONDITIONS

Study	Receive C/N						
	Type A	Type B	Type C	New 1	New 2	New 3	MCF
	19.7			14.06			-20.02
	(22.7)			(14.7)			(3.0)
Case I	21.7*			14.52*			-14.67*
	(22.7)			(14.7)			(3.0)
	17.8			10.79			-16.17
Case II	(19.0)			(11.0)			(-1.30
	12.3	13.5	13.8	13.6	13.93	13.97	-20.05
Case III	(14.0)	(14.0)	(14.0)	(14.0)	(14.0)	(14.0)	(-1.0)

* 12 MHz frequency separation between SS and TV carrier.